On the Palæozoic Rocks of Lehigh and Northampton Counties, Pennsylvania.

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The Palæozoic rocks of Lehigh and Northampton counties are :

The Potsdam Sandstone (No. I).

The Magnesian or Auroral Limestone (No. II).

The Trenton Limestone (No. II).

The Utica Shale (No. III).

The Hudson River or Matinal Slate (No. III).

The Potsdam sandstone is first found in the outlying peninsula of the South Mountains, known as Lock Ridge, where it occurs on the north-west flank of the hill and undoubtedly has a north-west dip, those dips observed to the south-east being due to a sinking down of the rock at its exposure, where the underlying gneiss has been removed. It next occurs in two small patches on the northern flank of the main range of the South Mountain near Macungie (formerly Millerstown). A small patch of it is also found associated with the gneiss, where the latter crops out through the limestone in the gorge of the Little Lehigh Creek at Jerusalem Church, two miles north-west of Emaus. But it is first seen to any great extent along the north flank of the main range just south of Emaus, where its occurrence is constant, but of varying thickness, and continues for a distance of four and a half miles, after which it can no longer be traced.

It occurs again at the ridge of the South Mountain, close to Allentown, which forms the southern barrier of the Lehigh River, between Allentown and Bethlehem, where the sandstone is about twenty-five feet thick and extends with a few intervals (where it has been cut out by the river) the entire distance between these two places. It also extends across the Lehigh and forms the capping rock of a portion of the gneiss just east of Allentown and north of the Lehigh. The contact between the gneiss and sandstone is distinctly seen about two miles east of Allentown on the Lehigh Valley Railroad track.

The very lowest beds of the Potsdam sandstone are actual pudding-stones, containing pebbles the size of a man's fist and larger, and fragments of red, unaltered orthoclase. The upper beds are composed of a hard, compact quartzite containing greater or less quantities of feldspar nodules, which weather out and impart to the rock a pock-marked appearance. When first quarried the color of this quartzite is blue to bluish-gray, which on exposure soon changes to a dark reddish-brown, due to the oxidation of the ferrous oxide it contains. The change from a pudding-stone to a compact quartzite in the sandstone shows that there has been a gradual sinking of the earth's crust and an increase in the depth of the sea, thus preparing the way for the subsequent deposition of the limestone.

The Potsdam sandstone often, as elsewhere, contains *Scolithus*.

Next above the Potsdam sandstone occur hydromica slates, which Rogers has called the Upper Primal Slates, but which really form a portion of the No. II limestone, and gradually pass into this. They overlie the Potsdam conformably and are far more persistent in their occurrence, continuing with few intervals the entire distance from the western boundary of Lehigh county to the Delaware River. They lie along the north flank of the South Mountain and overlie the Potsdam conformably wherever this is visible. They are of great economic importance as carrying the lowest range of brown hematite iron ores, to be mentioned later.

These slates are composed in great part of the mineral damourite and occur of a pink, gray, white, and yellow color. When exposed to the weather they very rapidly decompose to soft unctuous plastic clays in a few days, and some of these will in time probably become valuable in the manufacture of coarse kinds of pottery. Generally they contain more or less of the carbonates of lime and magnesia and silica mixed with the damourite.* Hydromica slate also occurs the greater portion of the distance from the western boundary of Lehigh county to the Delaware River, at the junction of the No. II limestones with the No. III slates, here also carrying brown hematite ores in extensive deposits.

It also occurs intercalated in the limestone, forming layers from the thickness of a sheet of paper to several feet, and these layers are innumerable. Their existence has been seen both in rock outcrops as well as in wells which have been sunk.

The clay to which the hydromica slate decomposes is generally of a white color, although sometimes brown from the presence of hydrated ferric oxide. Analyses would seem to show that the clay contains rather less potash than the undecomposed rock.

Overlying the hydromica slates, and conformable with these and the Potsdam sandstone, is the No. II or Magnesian limestone (Auroral of Rogers), which extends as a great mass varying from six to seven and a quarter miles in width. At four points gneiss crops out through the limestone. These are at Chestnut Hill north of Easton, at a hill two miles north of Bethlehem, the gneiss ridge north of the Lehigh, between Allentown and Bethlehem, and at Jerusalem Church, two miles north of Emaus. Otherwise its continuity is unbroken.

In its lower beds the limestone contains large quantities of chert, forming nodular masses of very various sizes and usually having their longest axes conformable to the bedding of the enclosing rock. This chert occurs in the manner described by Safford† as characteristic of the Knox dolomite of Tennessee. It disappears, however, in the upper strata.

* Report of Progress for 1874 of Lehigh Dist. Geol. Survey of Pennsylvania, p. 12.

† See *Geology of Tennessee*, by Safford, p. 215, 218.

The limestone varies from a blackish-blue to dove color, being for the most part compact to semi-crystalline, while there are occasionally shaly beds. In composition it varies much, often approaching a true dolomite, again a pure limestone. But from the isolated analyses made it would seem as if the percentage of magnesia was less in the upper beds than the lower ones. The limestone is always siliceous, often very much so, and hence much care is now being taken by many of the iron-masters in selecting beds of it, as a flux in their furnaces, which are low in silica, so as to be suitable for smelting the iron ores of the Great Valley and New Jersey, which are also high in silica. It often contains minute grains of pyrite disseminated through it, which weather out on exposure, leaving minute cavities behind. Numerous analyses have shown the presence of ferrous carbonate varying in amount from 0.538 to 1.305 per cent.

A peculiarity of the limestone is that it is often brecciated, the fragments being composed *exclusively of limestone*, cemented together by calcite or dolomite. The brecciated appearance is rarely visible on fresh fracture, being usually brought to view by weathering. When seen in place it will usually be found that one or more brecciated beds occur between two others which do not exhibit this peculiarity. As the beds of the No. II limestone have been much disturbed by the force which elevated the South Mountain range, the probable explanation of this brecciation is that a very hard, unyielding bed occurs between two more pliable ones; that these, when subjected to the lateral thrust of the uprising mass of the South Mountains, have conformed themselves to the folds of the strata, while the harder one, being unable to do this, has been fractured and *re-cemented in sitû* by the percolation of calcareous waters.

Some observers have supposed that the No. II formation is actually composed of two limestones, the lower one belonging to the Huronian, the upper to the Calciferous; and patches of the latter are supposed to overlie the former. The upper limestone (according to these observers) having been formed from the lower, the brecciated limestones are adduced as evidences of upheaval and shore action.

The explanation I have offered of the formation of the brecciated limestone is both more in accordance with the facts observed and with the generally accepted view of the deep-sea formation of limestone than the hypothesis above stated; for the brecciated limestones are as common near the base of the series as the top.

Besides the genus *Monocraterion* found in the Lehigh county limestone belongs to the same family as *Scolithus*, and is therefore no greater proof of age than the latter; and it occurs in but one locality close to the top of No. II, having not more than fifty to one hundred feet from the overlying Calciferous and Trenton.

The fossils thus far found in the No. II limestone do not number a dozen specimens, and have been found in but four localities. At Helfrich's Spring, about two and a half miles north of Allentown, the Jordan makes a great bend around a limestone hill, and, by an underground passage of a portion of its water, has excavated a cave a short distance into it. At the west end of the hill, near the small opening where that portion of the creek forming the spring disappears, there occurs a new species of Monocraterion, as yet undescribed. Of this half a dozen casts have been found ; but all efforts to discover the fossil itself have been hitherto unsuccessful. This discovery is the more interesting as the genus *Monocraterion* has hitherto only been known to occur in Sweden.

About half a mile north-east of this five or six specimens of a lingula were found in John Schadt's quarry, but it is impossible to determine its species. About half a mile west of Helfrich's Spring a single specimen of an orthoceratite was found close to the Jordan, just north of Scherer's Tavern, but so imperfect that its species is undeterminable. Finally a specimen of Euomphalus was found on Nero Peters' farm, two miles east of Ballietsville.

Not a single fossil has been thus far found in the No. II limestone of Northampton county.

The No. II limestone, like the Magnesian limestone of the Mississippi Valley, is exceedingly soluble. Streams constantly disappear in the ground, forsaking their original beds except when the volume of water is too great to be carried off by the subterranean channels, and reappearing again as springs at greater or less distances. The effects due to this solution of the limestone are very great. Not only are small sink-holes very common, but beds are found often much contorted locally in a manner which can only be explained by supposing them to have dropped down by their own weight into caverns excavated by the water beneath them. Possibly also the contortion of the hydromica beds as developed in the brown hematite mines at the junction of the limestone with the No. III slates is due to the same action, rendered more prominent by the passage of streams from the slate to the limestone, where the solving action could begin. The different beds too are soluble in very different degrees ; some apparently yield at once to the eroding action of water, while others afford a resistance to this operation for reasons as yet unknown, but which are probably rather mechanical or physical than chemical. Knowing as we do so little as to the conditions under which the different layers of limestone, almost or quite identical in composition, were formed, we can only speculate that those layers which resisted erosion were more compact, hard, and dense, perhaps more metamorphosed by a subsequent crystallization than the others, while we actually have no facts on which to base such theories. No better illustration of the darkness amidst which geologists are seeking light can be given than by stating that we are in complete ignorance of the causes which produce different layers of limestone, almost identical in composition, the one above the other. We can explain alternations of shale, sandstone, and limestone by changes in depth of the sea in which they were formed ; but such an explanation does not hold good where the same rock continued to be formed. Why should the sediment, whether chemical or mechanical, have formed a continuous layer an inch to several feet in thickness, and then a break in continuity have occurred, to be succeeded by another layer of the same material?

While the greater portion of the limestone has in all probability been formed in deep water, we have one instance in a quarry in Uhlersville on the Delaware where it must have been formed as a beach, since we find here distinct traces of ripple marks along the entire face of the quarry, some sixty feet high and fifty feet deep, the strata being tilted nearly vertically.

It has been generally supposed that the limestone dips almost universally southward; and while this view holds good for Northampton county, except at the junction of No. II with the No. III slates and along the north flank of the South Mountains, it is not the case in Lehigh county; for here we find north-west dips, more especially along an axis which is prolonged some distance into Northampton county, a short distance above Catasauqua.

As a general thing the limestones pass conformably under the No. III slates, and the few exceptions where the slates dip towards the limestones, and the latter away from the slates can readily be explained by an overturning of the beds towards the south, by which means as in the slate quarry close to and south of Ironton the slate apparently passes conformably below the limestone.

Overlying the No. II limestone occurs the Trenton limestone which is more fossiliferous and contains such characteristic fossils as *Chœtetes lycoperdon* and *Orthis pectinella* as well as the stems of an encrinite. It was first found about a mile south of Ironton in Lehigh county, then at intervals between Bath and Martins Creek in Northampton county; but all attempts to trace it as a continuous formation have thus far been unsuccessful owing to the lack of outcrops. It occurs most extensively at Martins Creek on the Delaware, at a point a little south of the cotton mill, and is there as elsewhere apparently conformable with the underlying Magnesian limestone.

This limestone resembles in appearance the No. II, being however more compact and not at all crystalline and of a gray black color.

There has been no apparent sudden break between the two, but the transition has been a gradual one. This was to be expected if the subsidence of the sea-bottom was steady and slow. An examination of the beds between Ironton in Lehigh county and the Delaware River, as close to the junction of the limestone and slate as possible, has shown that the limestone for the entire distance is more or less of a hydraulic one, due to the greater proportion of alumina which it contains. This also was to be expected if the subsidence continued. as signalling an approach to the era of slate-formation and open sea deposition. These limestones are utilized on the Lehigh river in the manufacture of hydraulic cements and lately Portland cement has been made at the Copley Cement Works, which is said to be nearly or quite equal to the imported. Careful search and the demand for it will no doubt cause this variety of the limestone to be explored at various other points in the two counties, and will in time render us independent of the cement now sent from the Hudson River. The limestone is of a dull, earthy appearance, entirely free from any crystalline texture and of a dark grey color.

Before closing our discussion of the limestone it is necessary to speak of the large and numerous deposits of brown hematite iron-ore which occur in it, and which form the main support of the extensive iron furnaces of the Lehigh and Schuylkill Valleys.

The brown hematite iron-ore occurs almost exclusively in two irregular lines of deposition; the one along the northern flank of the South Mountain Range, the other at or near the junction of the No. II limestone with the No. III slates. A few other localities occur, at which the ore is found, but these are insignificant in number compared to the two lines mentioned. Along both these lines the ore is always found either in hydromica slate, or resting on limestone very greatly impregnated with damourite; the same is true elsewhere whenever the brown hematite is found *in loco originali.* Some deposits are however found which have evidently been pockets or cavities in the limestone into which the masses of limonite have been forced together with gravel and clay during the Drift Period. Leaving these out of consideration as of minor importance, let us consider briefly those iron-ore deposits which occur in place. It is at once evident that like the rocks with which they are associated they are of secondary origin, and have been derived from still older formations. The occurrence of the brown hematites with silica, alumina, lime, magnesia, and the alkalies, more especially potash, points to their having been derived from Archæan rocks containing orthoclase and either hornblende or pyroxene. From the decomposition of these three minerals we are able to derive all the oxides above mentioned including the iron which was without any doubt derived in great part from the decomposition of ferrous siliciate present in the hornblende and pyroxene, while a portion of the iron may have been derived from iron pyrites, although this supposition is entirely unnecessary. It is extremely improbable that the brown-hematite was derived from the per-oxidation and hydration of magnetic iron ore, when we recall the great resistance which the latter offers to chemical change of any kind when exposed to the action of air and water, and its unaltered condition and fresh, bright appearance in rivers and on the seashore. But the question as to how the brown hematite got into its present condition and whether it was deposited cotemporaneously with the rocks containing it, or subsequently to these, is still an enigma and various theories have been offered in explanation. For a resumé of some of these hypotheses reference may be made to a recent article by Prof. J. D. Dana, in Vol. XIV, III series Am. Jour. Sci. and Arts, p. 136. The almost entire freedom of the hydromica slate, when fresh, in Lehigh and Northampton counties from ferruginous minerals will prevent our having recourse to pyrite, pyrrhotite, chlorite, garnet, mica and staurolite, which Prof. Dana says occurs in the hydromica region of Connecticut. Hence we must have recourse to other sources. It seems most doubtful that the mineral, from which the brown hematites were derived, was deposited cotemporaneously with the hydromica slates in the district under discussion, since we find the ore often passing through the slate or clay obliquely and intersecting the bedding. It is more probable that the ore was conveyed to its present position by infiltration subsequent to the formation of the hydromica slates. Whence was it derived? I have already stated that the limestone contains varying proportion of ferrous carbonate and of pyrite and when we consider the enormous erosion which the limestone has undergone, the wonder is not that the deposits of iron ore should be so great, but rather that they should be so small. The ferrous carbonate and the pyrite oxidised to ferrous sulphate being both soluble in water, the former when the water contained carbon di-oxide, the waters would naturally carry these salts in solution until they came in contact with precipitating agents such as the alkaline silicates which the hydromica slates carry. These last became converted to carbonates and sulphates, leaving the iron behind, either directly as hydrated ferric oxide, or possibly as ferrous silicates which became later decomposed by the action of ærated water to hydrated ferric oxide and free silica, which latter we now find so universally associated with the brown hematites as quartz. Whatever the origin of these ores may have been, one thing is evident, *viz.*, that there is some genetic relation between the brown hematites and the hydromica slates, as evidenced by the almost universal occurrence of the ore in the slate, extending all the way from Vermont to East Tennessee through the Great Valley as well as in the interior valleys of Pennsylvania where the No. II limestones occur.

It is well here to emphasize the fact that these brown hematite ores all belong to the Lower Silurian limestone formation, since, in 1875, Dr. Sterry Hunt after a cursory examination of Ziegler's Mine in Berks County, situated at the junction of the No. II limestone and the No. III slates, made the mistake, in a paper on "The Decay of Crystalline Rocks" before the National Academy of Science, of supposing that the hydromica slates belonged to the Huronian Period. A mistake into which so eminent an observer as himself would never have fallen had he been better acquainted with the region.

At intervals along the junction of the limestones and slates there occurs a black carbonaceous shale, often decomposed to black or dark blue clay, which I have supposed to be the representative of the Utica shales. It consists of a very carbonaceous hydromica slate (containing damourite), without any fossils and may not belong to the Utica Period at all. In no instance has it been found more than one to twelve feet thick, but it sometimes carries pyrite from which a portion of the iron ores, just mentioned, may have been derived. These shales are of no economic importance.

Overlying these come the No. III, Hudson River or Matinal Slates, which extend into the Kittatinny Mountains. A large portion of these slates are extremely useful for roofing and other household purposes, and extensive quarries have been opened at various points for the purpose of extracting them, as, however, they have been but very slightly examined, during the progress of the present Geological Survey of the State, I shall defer a more detailed description of them to some future time.